From SDSS to JDEM : Lessons I Learned

Nikhil Padmanabhan[1]

[1]Lawrence Berkeley Labs

11-20-2008 / Great Surveys

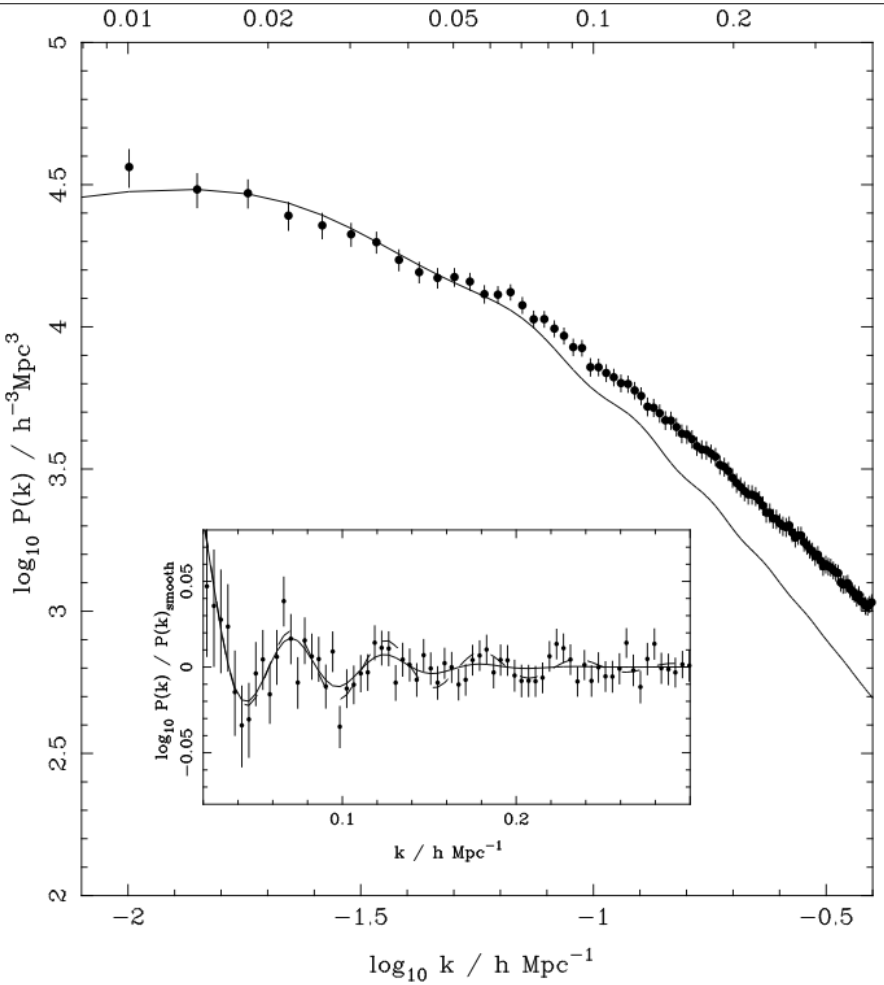
Outline

Outline

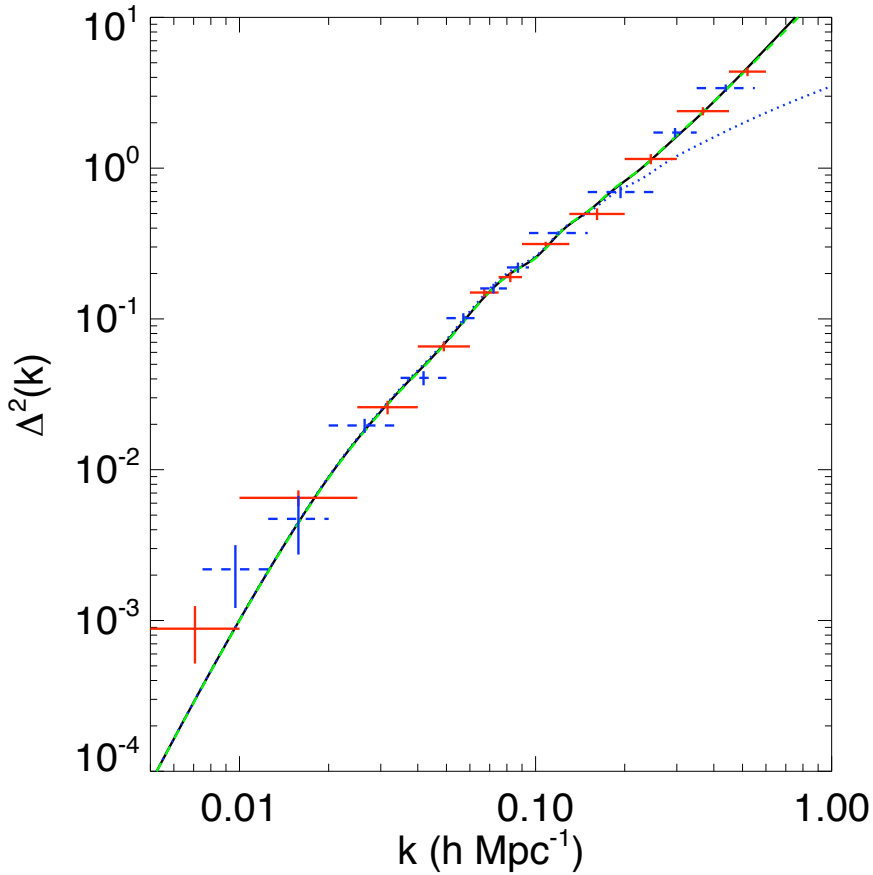
Is Photometry enough??

- Clearly not! But how much can we actually learn?

Large Scale Structure

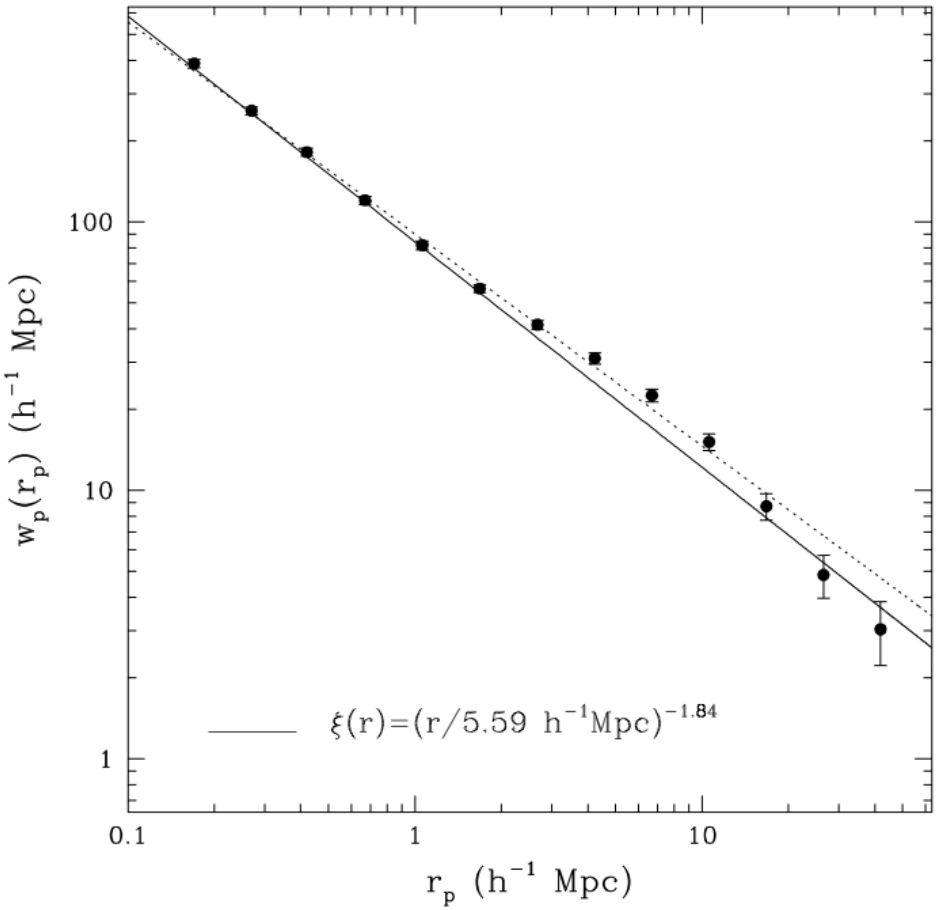


Percival et al, 2007

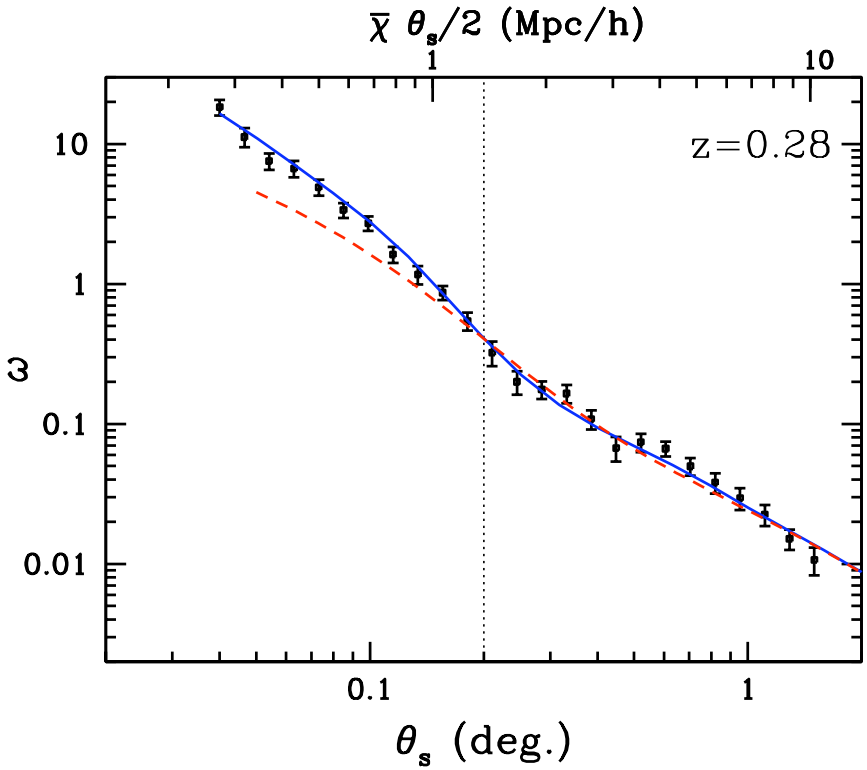


NP et al, 2007

Galaxy Clustering

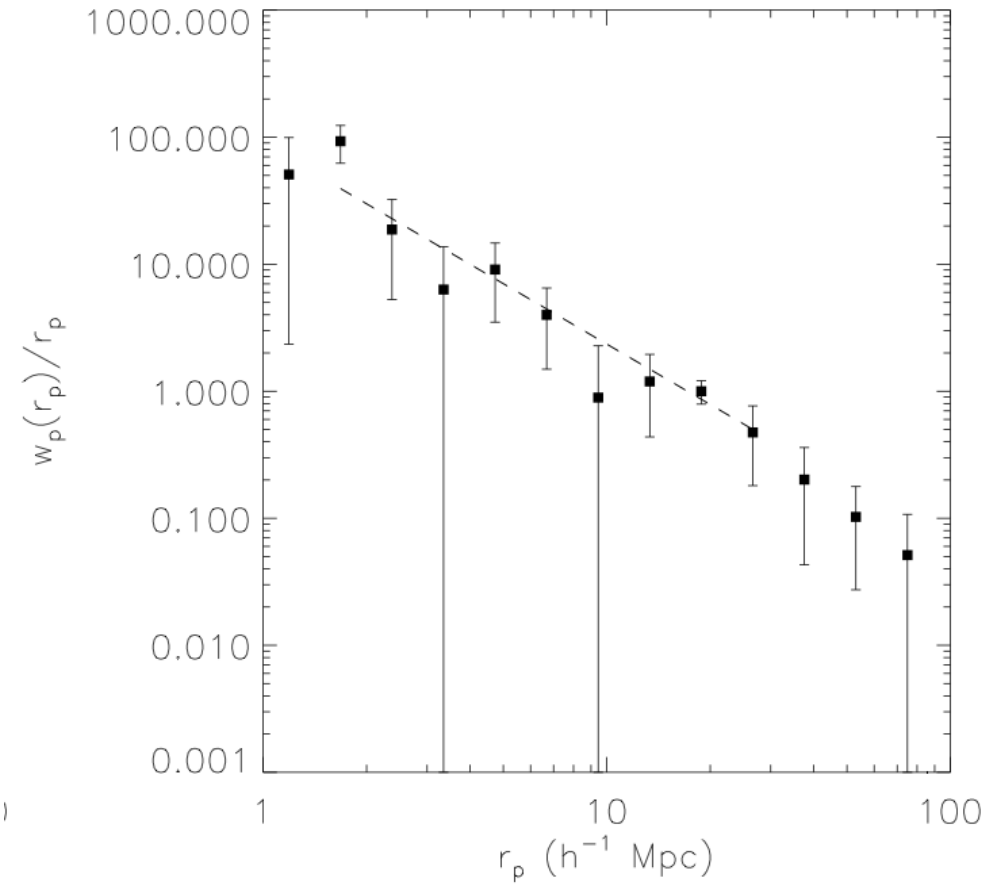


Zehavi et al, 2005

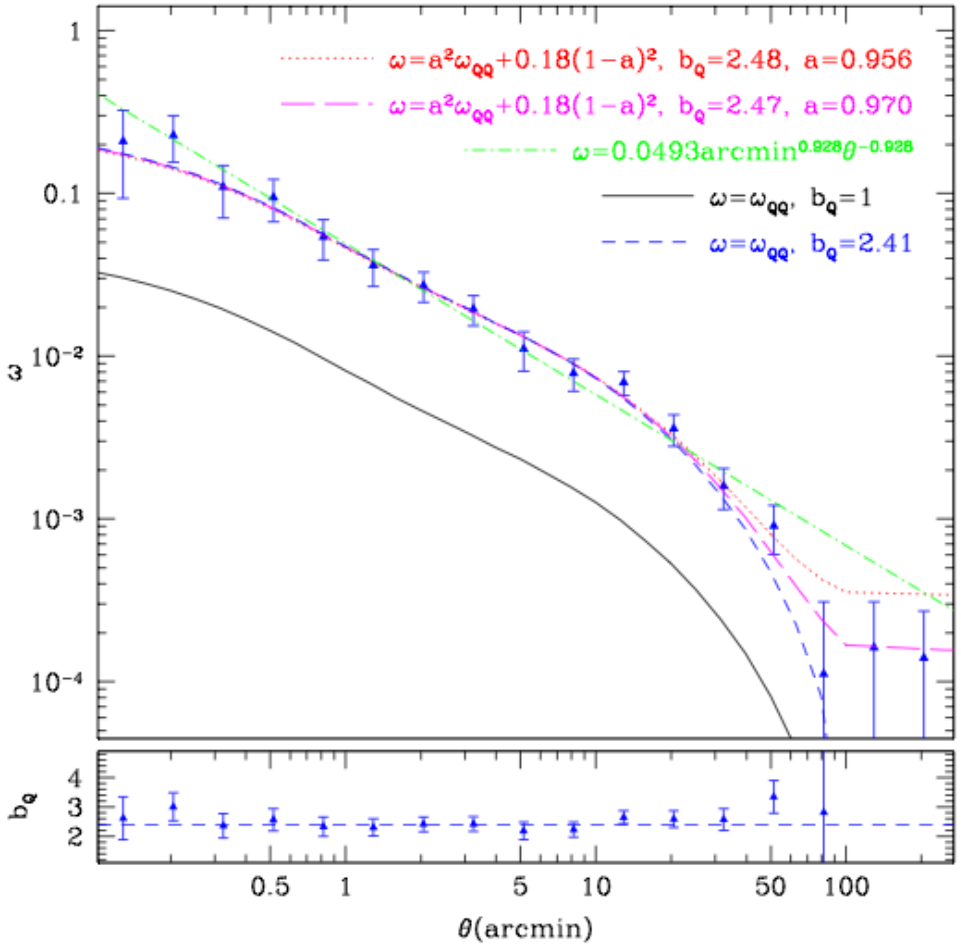


NP et al, 2008

Quasar Clustering



Shen et al, 2007



Myers et al, 2006

Is Photometry enough??

- Clearly not! But how much can we actually learn?
- With good photo-z's, lots of science possible.
- Complementary
  - Higher redshifts
  - Larger luminosity ranges
- Photo-z calibrations essential
- Some science not possible : eg. AGN activity, redshift space distortions, detailed spectral modeling
- How far can we go with just redshifts? ([G/P]rism surveys)
- What do we need spectra for? What resolutions?

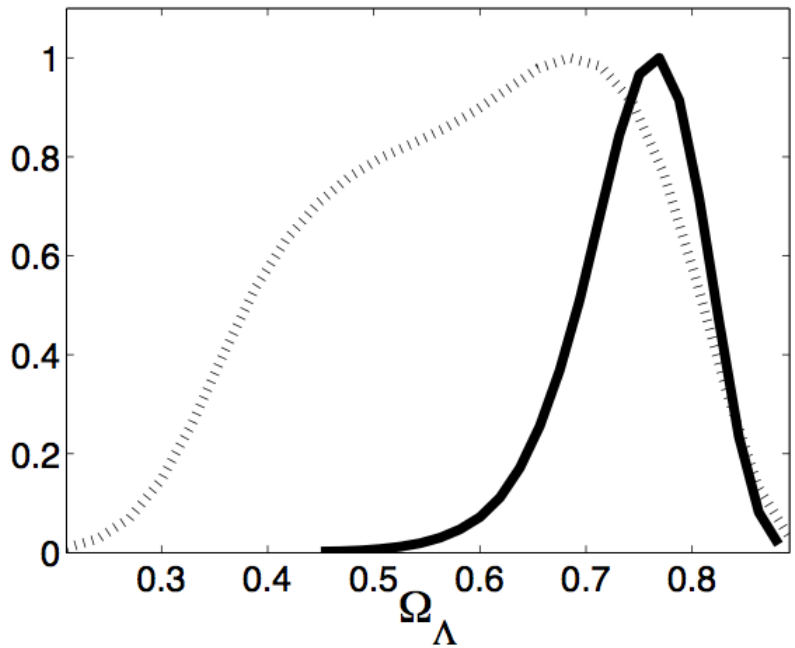
Outline

Whole $\neq$ Sum of Parts

- Lots of surveys! What do we learn by combining surveys?
- Ask questions of surveys that individual surveys will find hard (impossible?) to answer.
- Design surveys thinking about cross-correlation possibilities.
- Combining spectroscopic and photometric surveys
- Combining surveys of different wavelengths

The ISW effect

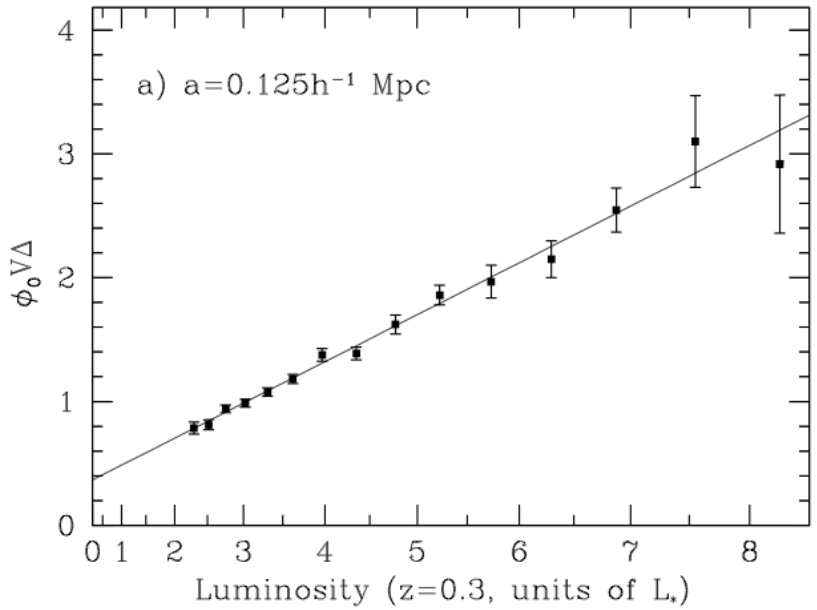
- The ISW effect constrains the late time acceleration.
- Hard to detect in the CMB due to cosmic variance
- 3.5σ detection in cross correlation with different galaxy samples.



Ho, Hirata, NP et al, 2008

The Environment of LRGs

- What is the environment of luminous red galaxies in SDSS?
- Very little overlap between SDSS MAIN and LRG samples
- Cross-correlate with the SDSS photometric sample (which goes much deeper).



Eisenstein et al, 2005

Outline

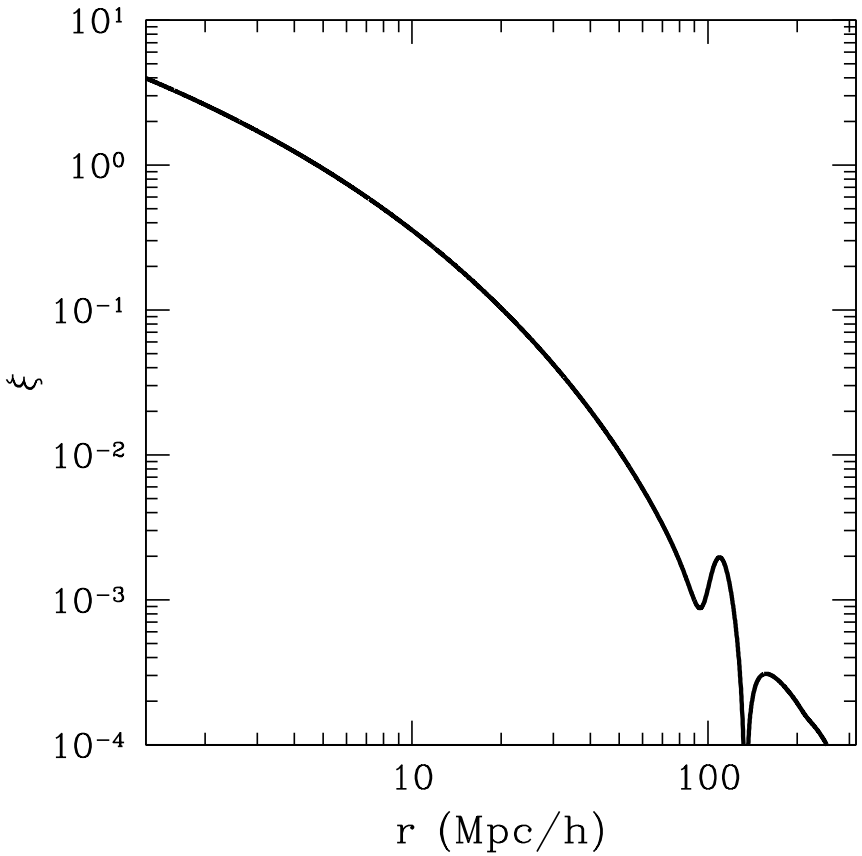
Probes of Dark Energy

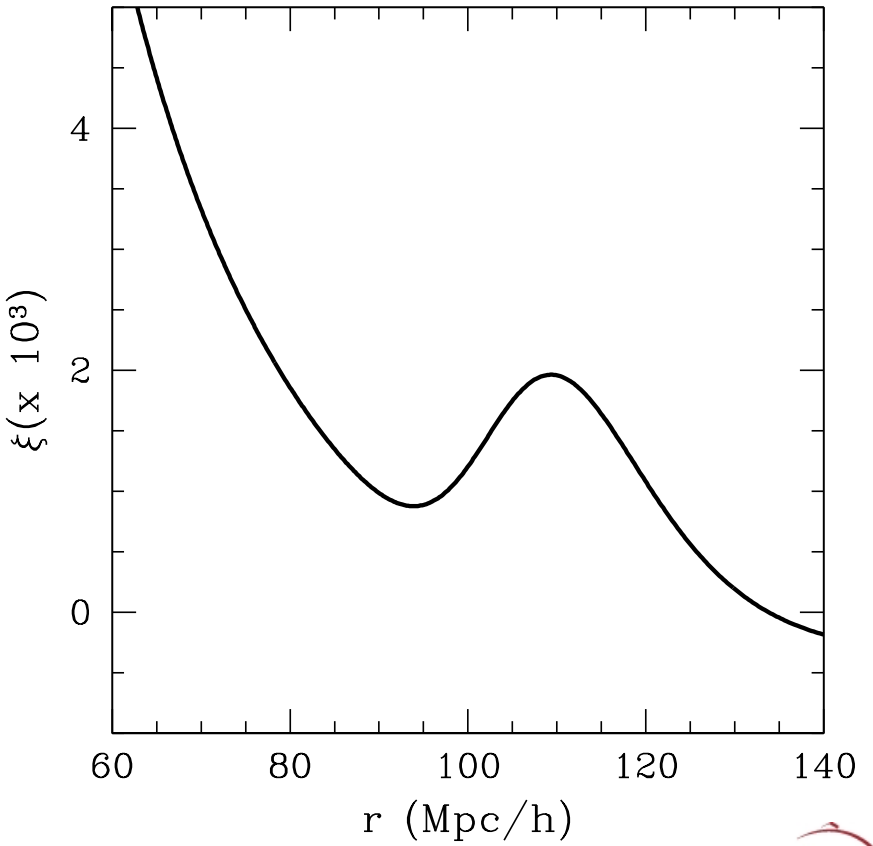
- The Homogeneous Universe
  - Constrain scale factor $a(t)$ as a function of time
  - Observations constrain $d_A(z)$, $d_L(z)$, $H(z)$
  - Geometrical probes
  - SNe – standard candles, **baryon oscillations** – standard rulers
- Inhomogeneous Universe
  - Constrain $\delta(t)$ – growth of fluctuations
  - Dynamical probes
  - Weak lensing, clusters, **redshift space distortions**

Standard rulers - completely analogous to standard candles!

The Correlation Function

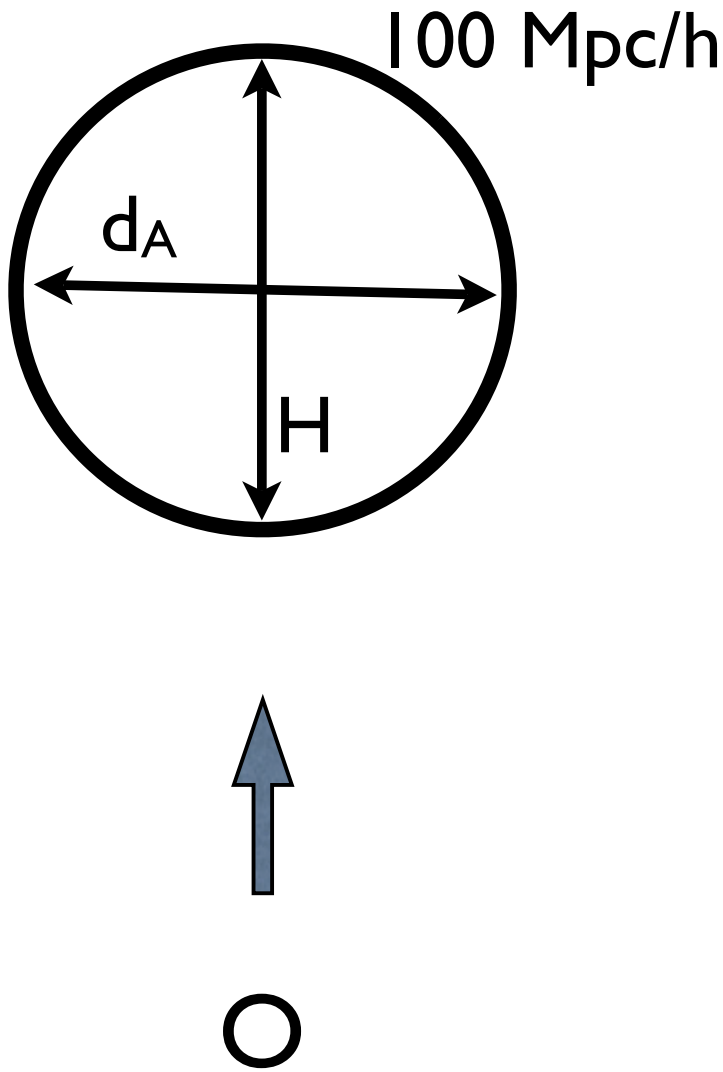
Use feature in matter correlation function as a standard ruler.
Use galaxies, neutral H as a proxy for matter.





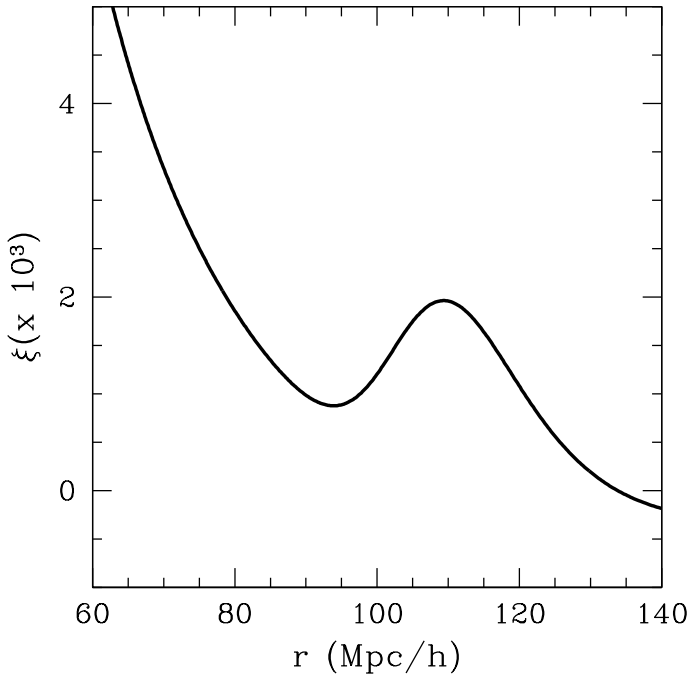
$d_A(z)$ and $H(z)$

- Measure feature $\perp$ and $||$ to line of sight
- $\perp$ – constrain angular diameter distance
- $||$ – constrain Hubble constant
- Internal consistency test
- More natural decomposition – dilations and warping (NP & White, 2008)



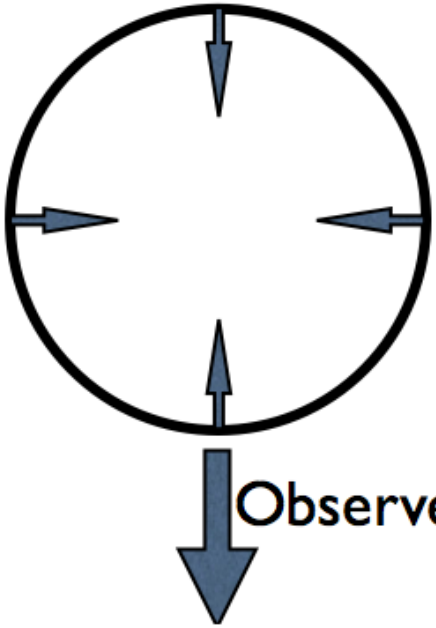
A Robust Ruler

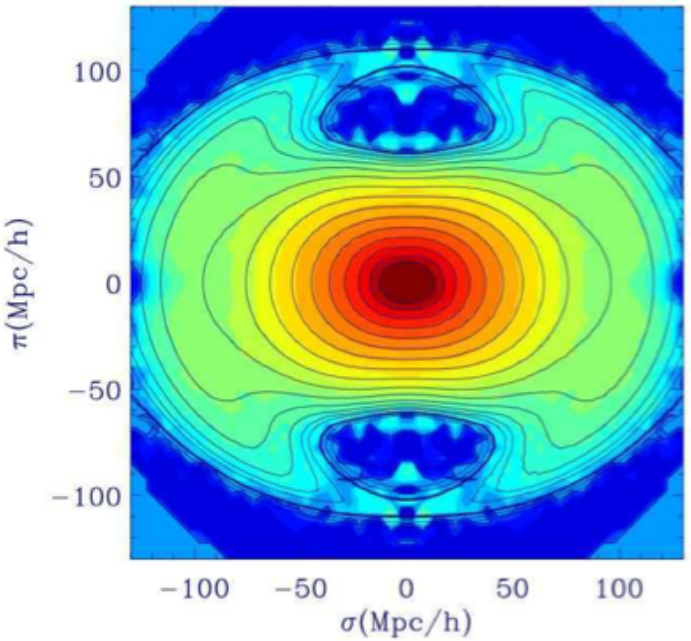
- Simple underlying physics
- Scale separation : $r_{\rm gal,nlin} \ll r_{\rm BAO}$
- Smooth effects on BAO scales, robust probe
- Expect small systematic errors
- More later!



Probing Growth

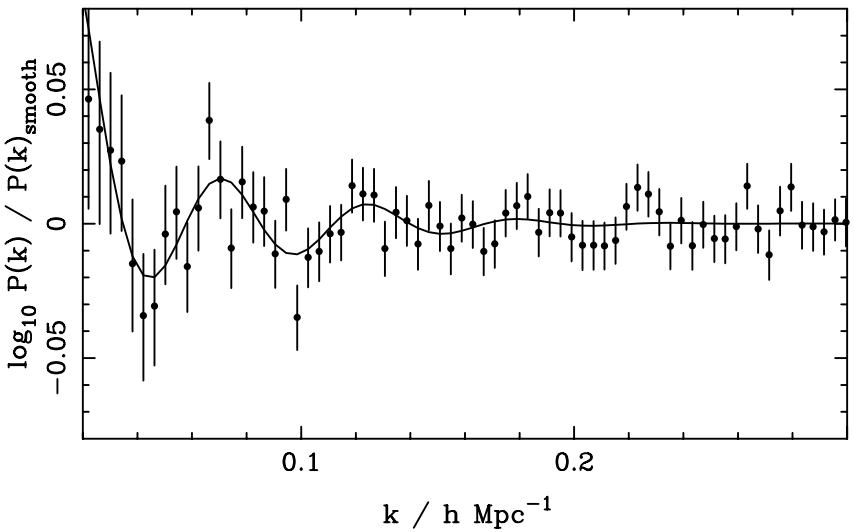
- Redshift space distortions
- Velocity field sensitive to matter distribution.
- Velocity field distorts the galaxy correlation function; makes it anisotropic – redshift space distortions.
- Measuring z-space distortions allow measurement of growth of structure.
- Independent probe of growth (i.e. not weak lensing); tests a different aspect of structure formation.





BOSS : A next generation BAO experiment

- How to do a precision $z < 1$ BAO expt.?
- After SDSS, then what?



Percival et al, 2006

- SDSS imaging detects red galaxies to $z \sim 0.8$ (2SLAQ, AGES)
- The SDSS spectrograph still is one of the best wide field MOS.

BOSS in overview

- Ω = 10,000 deg^2
- Fill in SDSS stripes in the south; 8500deg^2 in North, 3000deg^2 in South
- Luminous Red Galaxies : $z \sim 0.1 - 0.7$
- QSOs (Lyman-α forest) : $z \sim 2.3 - 3.3$
- 1% d_A, 2% H at $z \sim 0.35, 0.6$
- 1.5% d_A, H at $z \sim 2.5$
- Leverage existing hardware/software where possible
- PI : David Schlegel, SDSS-3 Director : Daniel Eisenstein
- The SDSS diaspora

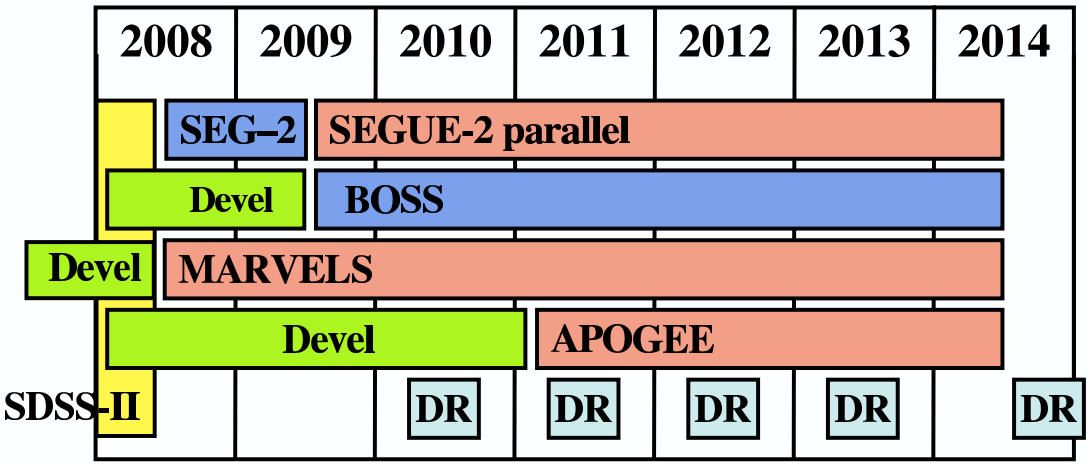
BOSS : A brief history

July 2006	Competitive proposal to use (upgraded) SDSS telescope for next-generation BAO experiment
Nov 2006	BOSS proposal selected (from 7) for all dark+grey time for 5 of 6 years
Nov 2006	First BOSS collaboration meeting (NYU)
Feb 2007	DOE R&D proposal for upgrading SDSS spectroscopic system
Oct 2007	Approval from Sloan foundation
2007	Funding proposals in to NSF and DOE
2008	Approval from NSF; R&D funding from DOE
July 15, 2008	SDSS-III begins
Sept 2008	BOSS imaging begins
Fall 2009-2014	BOSS spectroscopic survey at APO

http://www.sdss3.org/

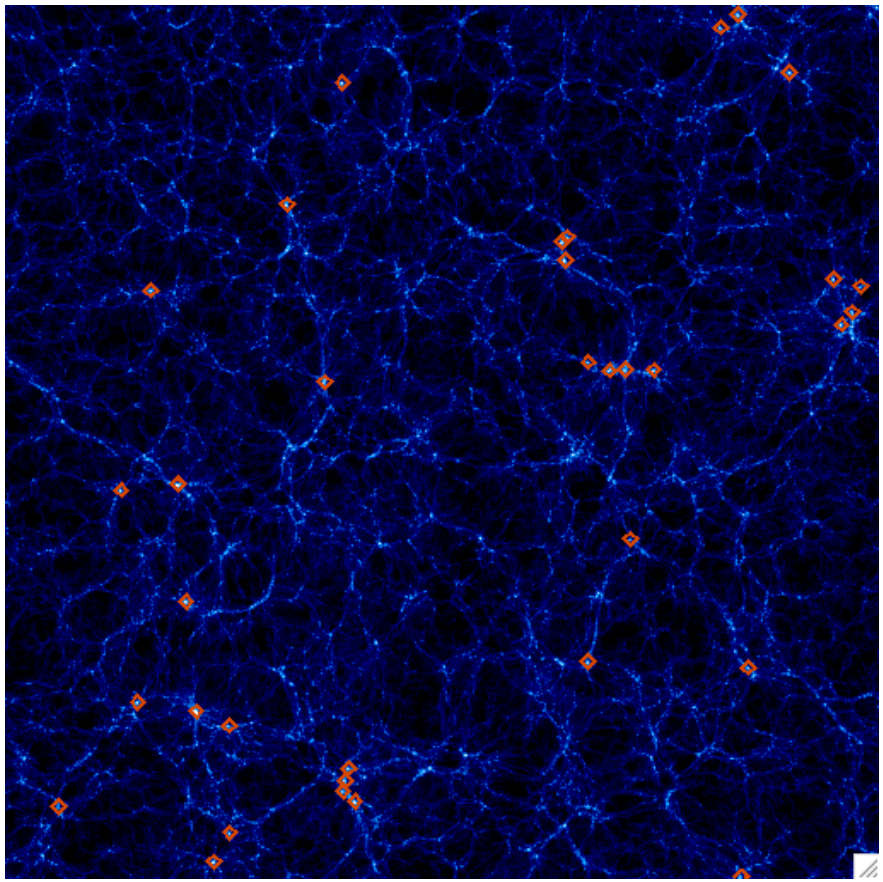
BOSS : As part of SDSS-3

- *SEGUE-2* : Kinematic and chemical structure from 350,000 stars in the outer Galaxy.
- *APOGEE* : High resolution IR spectroscopy of stars in the Galactic bulge, bar and disk.
- *MARVELS* : Radial velocity planet search around 11,000 stars
- **BOSS** : BAO with 1.5 million LRGs ($z < 0.7$) and 160,000 QSOs ($2.3 < z < 3.3$)



LRGs as tracers of LSS

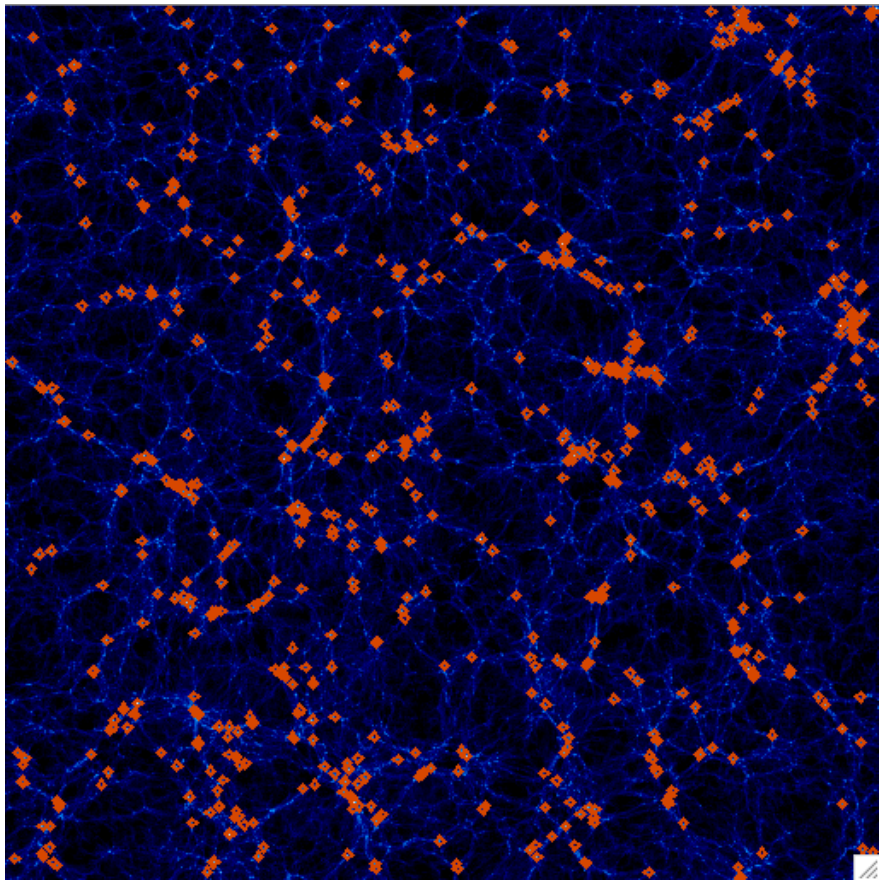
A slice 500 h^{-1} Mpc across and 10 h^{-1} Mpc thick.



SDSS, $z \sim 0.5$

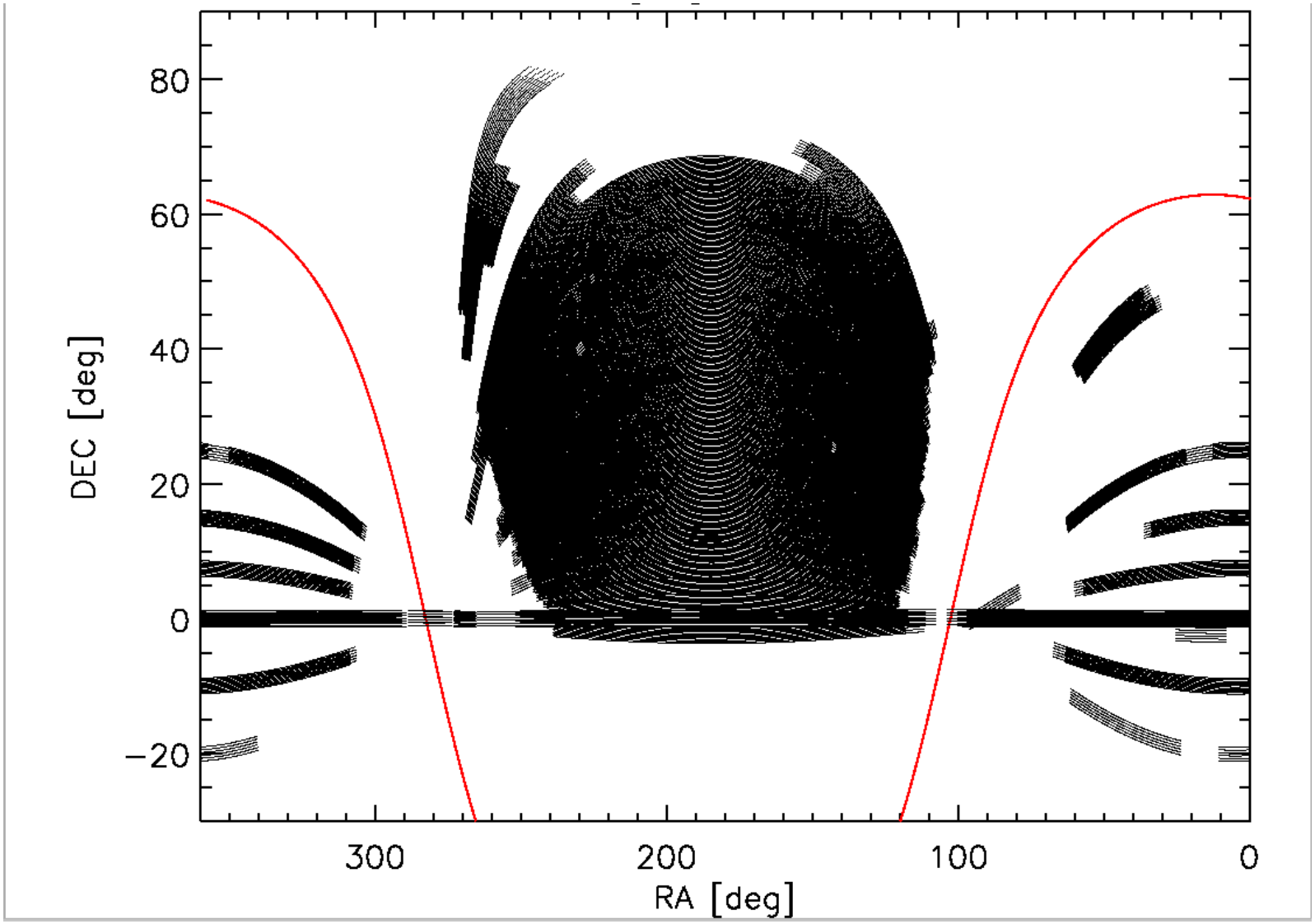
LRGs as tracers of LSS

A slice 500 h^{-1} Mpc across and 10 h^{-1} Mpc thick.



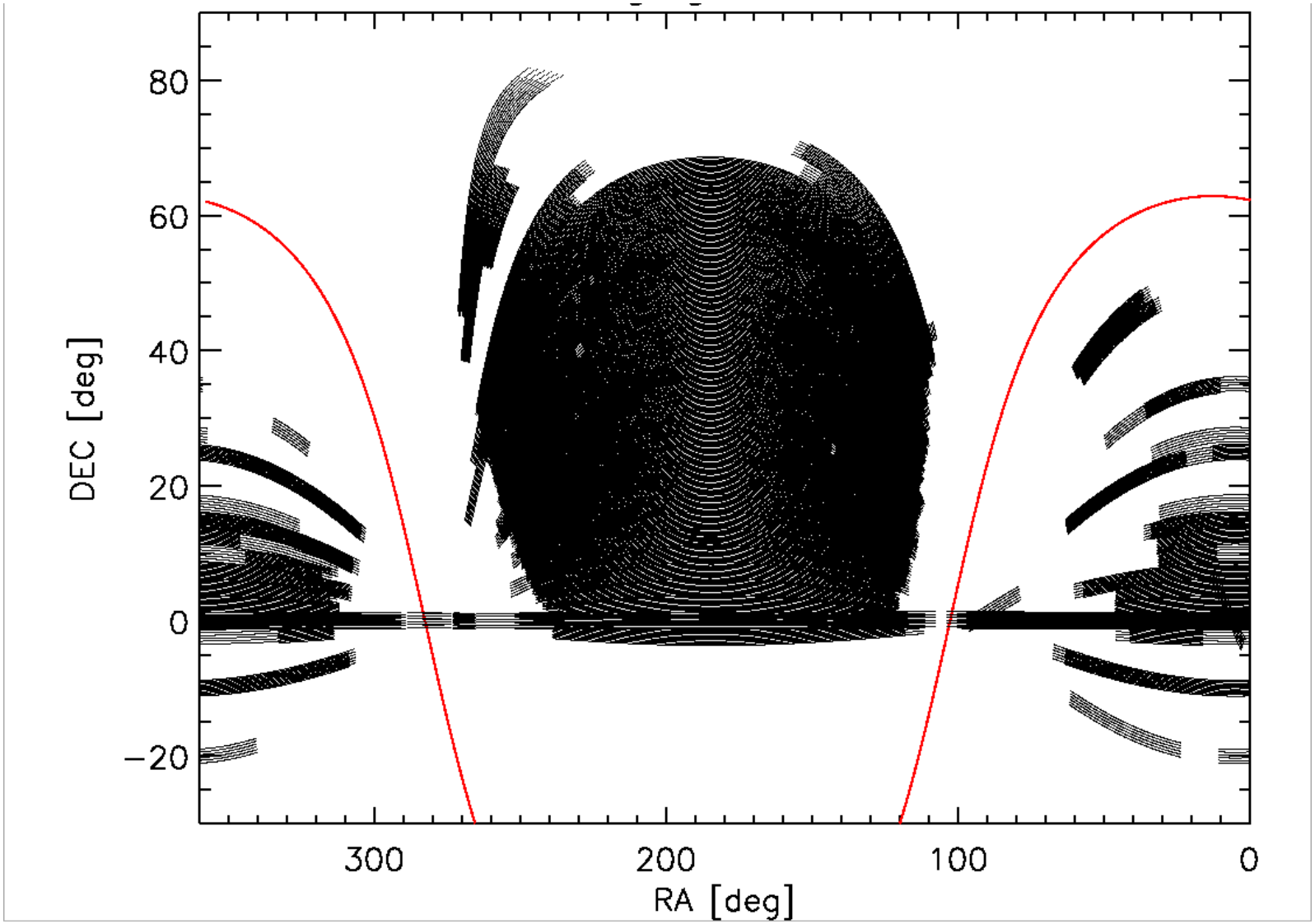
BOSS, $z \sim 0.5$

Imaging status



SDSS-II

Imaging status



BOSS

What's next for BOSS?

- *July 15, 2008:* SDSS-II ended, SDSS-III began.
- Complete 2-3000 deg^2 on imaging in the South in Fall 2008.
- Spectrographs being built right now, install in Summer 09.
- LRG/QSO spectroscopy Fall 2009 - 2014
- At which point, we should know....
  - $w_p = -??.?? \pm 0.03$, $w_a = ??.?? \pm 0.28$
  - $h = 0.?? \pm 0.008$, $\Omega_K = 0.?? \pm 0.002$

What's next for BOSS?

- *July 15, 2008:* SDSS-II ended, SDSS-III began.
- Complete 2-3000 deg^2 on imaging in the South in Fall 2008.
- Spectrographs being built right now, install in Summer 09.
- LRG/QSO spectroscopy Fall 2009 - 2014
- At which point, we should know....
  - $w_p = -??.?? \pm 0.03$, $w_a = ??.?? \pm 0.28$
  - $h = 0.?? \pm 0.008$, $\Omega_K = 0.?? \pm 0.002$

Next Generation Experiments

- **WiggleZ** : 1-2% distance measurements, $0.5 < z < 1.0$, *half completed*
- **BOSS** :
  - 1% distance measurements, $0 < z < 0.6$
  - 1.5% distance measurements, $2 < z < 3$, *new method*
  - *Started*
- **HETDEX** : 1% distance measurements, $2 < z < 4$
- **PAU** : 1% distance measurements, $0 < z < 1$, photo-z++
- ....

Note : Interesting numbers of redshift surveys coming on line in the near future.

More Cosmology

- Precision measurements of H_0 (1%), Ω_K (0.2%)
- Constrains $D(2)/D(1000)$ and $D(0.5)/D(1000)$ to 0.6% and 1% within ΛCDM
- Improved large scale structure constraints (250,000 modes with $k < 0.2$)
- Improved measurements from the Lyman-α forest
- Improved measurements of neutrino masses
- A S/N=200 measurement of ξ_{gm} from galaxy-galaxy lensing, direct probe of $D(z)$
- Constrain $f_{nl} <\sim 10$
- .....

Galaxy Formation/ Evolution

- Evolution of massive galaxies
- Improved QSO clustering measurements at $z > 2$
- Piggy-back program will double N_{QSO} with $z > 3.6$
- Synergy with next generation imaging surveys (eg. Pan-STARRS) [cross-correlation studies, galaxy-galaxy lensing]
- Synergy with current/ next generation CMB surveys (eg. ACT) [SZ, kinetic SZ]
- Serendipitous stellar studies (from QSO targeting)
- Spectroscopic detection of galactic scale strong lensing systems
- Projects we haven't thought of.....

Outline

... and JDEM??

- The design of JDEM is being worked out right now.
- JDEM aims to do supernovae, baryon oscillations, weak lensing.
- Likely will have an imaging and spectroscopic survey.
- Think of JDEM as SDSS in space.
- What is complementary to JDEM? LSST, low redshift 21-cm surveys,...
- JDEM will be much more than a dark energy measurement.